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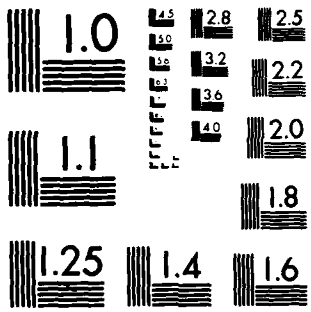

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ELECTROMAGNETIC WAVE SCATTERING BY PARTIALLY-BURIED METALLIC AND DIELECTRIC OBJECTS

FINAL REPORT

Professor K. K. Mei, Principal Investigator

March 1984

U. S. ARMY RESEARCH OFFICE

CONTRACT NO. DAAK-29-80-~~0100~~ 0010

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electromagnetic Scattering, Buried Targets, Lossy Ground, Dielectric Scatterers, Wave Scattering

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Electromagnetic wave scattering by buried and partially buried targets are studied. Results ~~have been~~ obtained for scattering by buried body of revolution, buried body of revolution with arbitrary orientation and two-body scattering.

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Introduction

The objective of this research is to study the feasibility of computing electromagnetic wave scattering by objects which are buried or partially buried in a lossy ground. The datas obtained through ~~the~~ computer solutions of the related Maxwell's Equations can be applied to detection of plastic land mines, tunnels and natural resources. The method used in this investigation is based on the Unimoment method, [1] which was developed by Mei of Electronics Research Laboratory. The method is a unique hybrid of analytical and numerical methods. The extension of the method to include lossy ground half-space was made possible by the development of special eigenfunctions which include the continuity conditions of the air-ground interface [2].

The basic idea of the Unimoment method is to separate the solution region into two parts. For the scattering problem, the boundary of the separation is a separable surface, such as a sphere in a three dimensional problem. Interior of the sphere, where the scatterer is located, numerical methods are used. Exterior of the sphere, where the median is simple and have known analytical general solutions, eigenfunction methods are used. The two solutions are then joined together at the separating sphere numerically to simulate the continuating conditions. The method has been successfully implemented for scattering in free space [3] and scattering by buried targets [4].

Accomplishments

The study of buried targets of [4] is for targets buried deep enough so that the Unimoment sphere (the separating sphere) is entirely under

ground. For partially buried or shallowly buried objects, the Unimoment sphere must penetrate the air-ground interface as shown in Fig. 1. Because of that, several changes must be made, and results studied, in order to investigate the validity of the method under those conditions. The changes include the mesh generation strategy, the trial functions on the Unimoment sphere and the convergence tests. These changes have all been studied and successfully implemented.

The typical mesh of a partially buried configuration is shown in Fig. 2. The actual scattering configurations are given in Fig. 3. The testing cases of moving the Unimoment spheres across the interface are shown in Figs. 4-5 which indicate that our effort for calculating a partly buried object will not be effected by installing the Unimoment spheres across the interface. Typical scattered near fields at the interface are shown in Figs. 6 and 7.

In addition to accomplishing the stated objectives, we have also succeeded in computing scattering configurations, where the axis of the target is not parallel to the normal of the interface. The scattering configuration and results are shown in Figs. 8-10.

Furthermore, we have also completed the investigation of scattering of two bodies near a lossy ground. The scattering configuration and typical results are shown in Figs. 11-13.

Publications

During the investigation the following papers have been published or are to be published.

(1) "Multipole Expansion Technique for Electromagnetic Scattering by Buried Objects," by S. K. Chang and K. K. Mei, Electromagnetics, vol. 1, no. 1, pp. 73-89, January 1981.

(2) "Scattering of Electromagnetic Waves by Buried and Partly Buried Bodies of Revolution," by H. S. Chang and K. K. Mei, to be published in IEEE Trans. on Remote Sensing and GeoScience.

The following presentations were made at conferences:

(1) "Scattering of EM Waves by Buried and Partly Buried Body of Revolution," by H. S. Chang and K. K. Mei, IEEE, Antennas and Propagation Society 1981 International Symposium, Digest pp. 653-656.

(2) "Recent Developments in Unimoment Method," URSI General Assembly, Symposium Digest, p. 390, Washington, DC, August 1981.

(3) "Unimoment Method for Electromagnetic Scattering," Symposium on Acoustic, Electromagnetic and Elastic Wave Scattering, Ohio State University, Columbus, Ohio, Oct. 1982.

The following Ph.D. Theses were completed:

(1) "Scattering of Electromagnetic Waves by Buried or Partly Buried Inhomogeneous Bodies of Revolution," by Henry S. Chang, June 1980.

(2) "On the Electromagnetic Wave Scattering by Buried Bodies of Revolution with Arbitrary Orientation," by Po-Shen Cheng, May 1983.

(3) "Scattering by Two Bodies Near Loss Ground," by Shigetoshi Yokota, September 1983.

During the investigation the following personnel were employed:

(1) Po-Shen Chen, (graduate student)

(2) Shigetoshi Yokota (graduate student)

(3) Kenneth K. Mei (Faculty)

The following papers are being prepared for publication:

(1) "Scattering by Buried Dielectric Bodies of Revolution of Arbitrary Orientation."

(2) "Scattering by Two Bodies Near Lossy Ground."

References

[1] Mei, K. K. "Unimoment method of solving antenna and scattering problems," IEEE Trans. on Antennas and Propagation, vol. AP-22, no. 6, pp. 760-766, November 1974.

[2] Chang, S. K. and K. K. Mei, "Generalized Sommerfeld's Integrals and Field Expansions in Two-Medium Half-Spaces," IEEE Trans. on Antennas and Propagation, vol. AP-28, no. 4, pp. 504-512, July 1980.

[3] Morgan, M. A. and K. K. Mei, "Finite Element Computation of Scattering by Inhomogeneous Penetrable Bodies of Revolution," IEEE Trans. on Antennas and Propagation, vol. AP-27, no. 2, pp. 202-214, March 1979.

[4] Chang, S. K. and K. K. Mei, "Multipole Expansion Technique for Electromagnetic Scattering by Buried Objects," Electromagnetics, vol. 1, no. 1, pp. 73-89, January-March 1981.

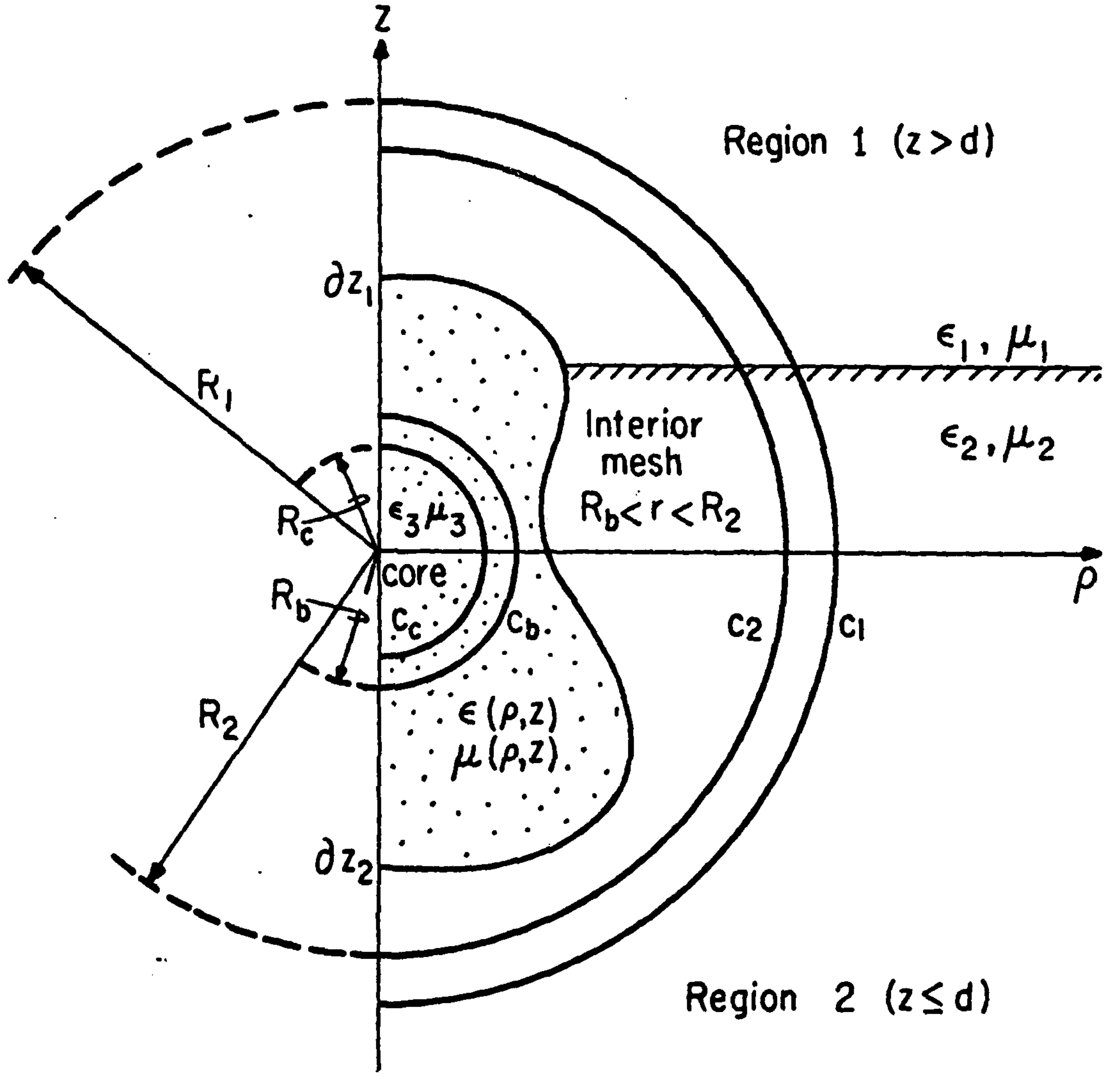

Figure 1. Unimoment Subdomain

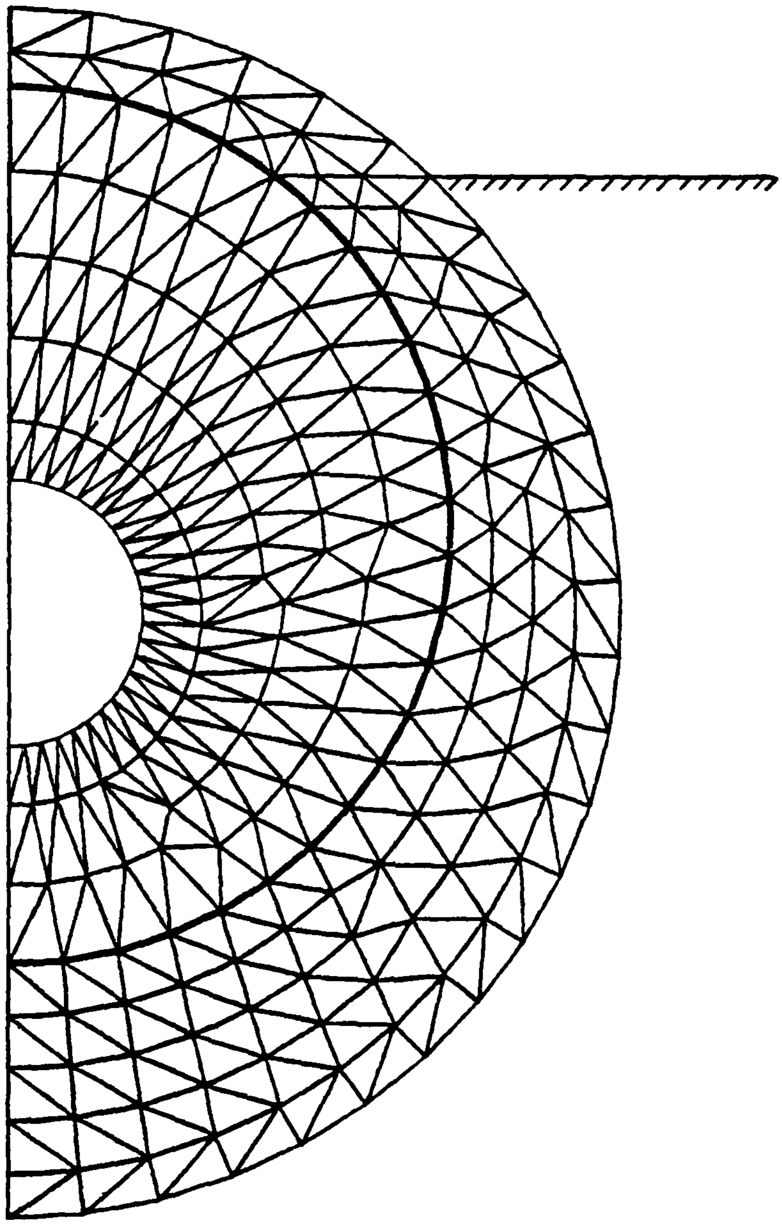

Figure 2. Finite Element Mesh for a Partly Buried Dielectric Sphere

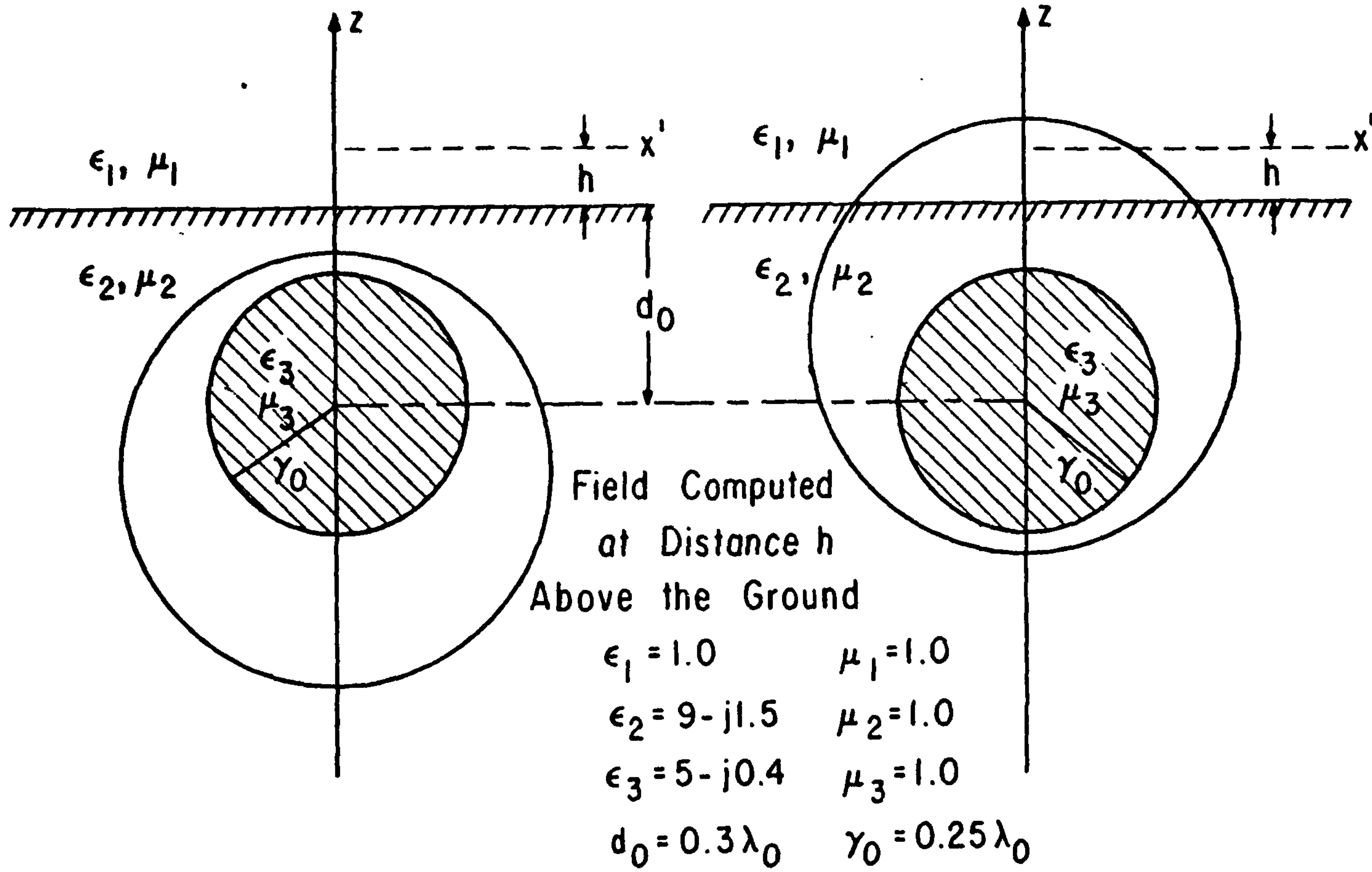

Figure 3. Offser Dielectric Sphere Configuration

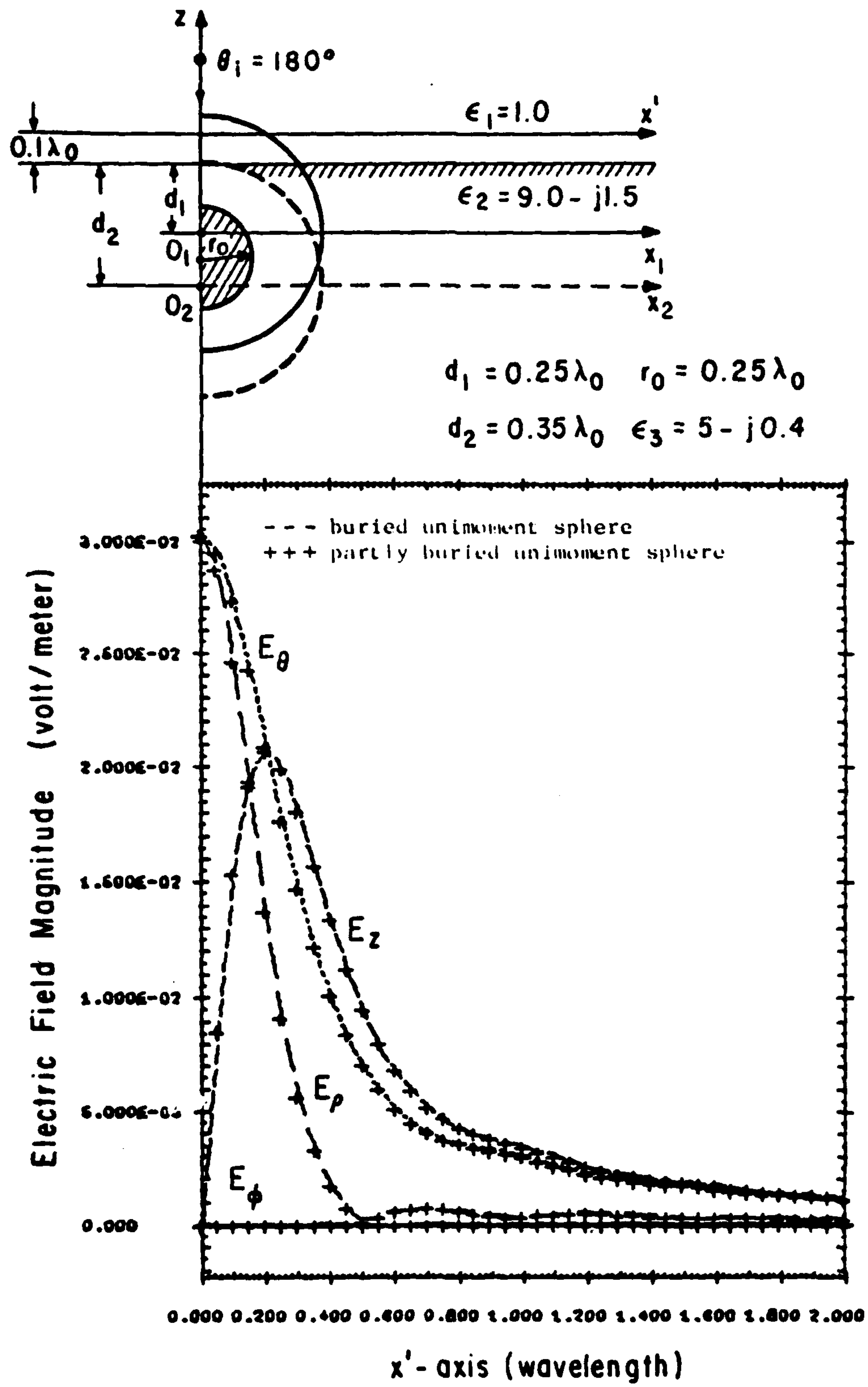

Figure 4. Near Field Above the Interface

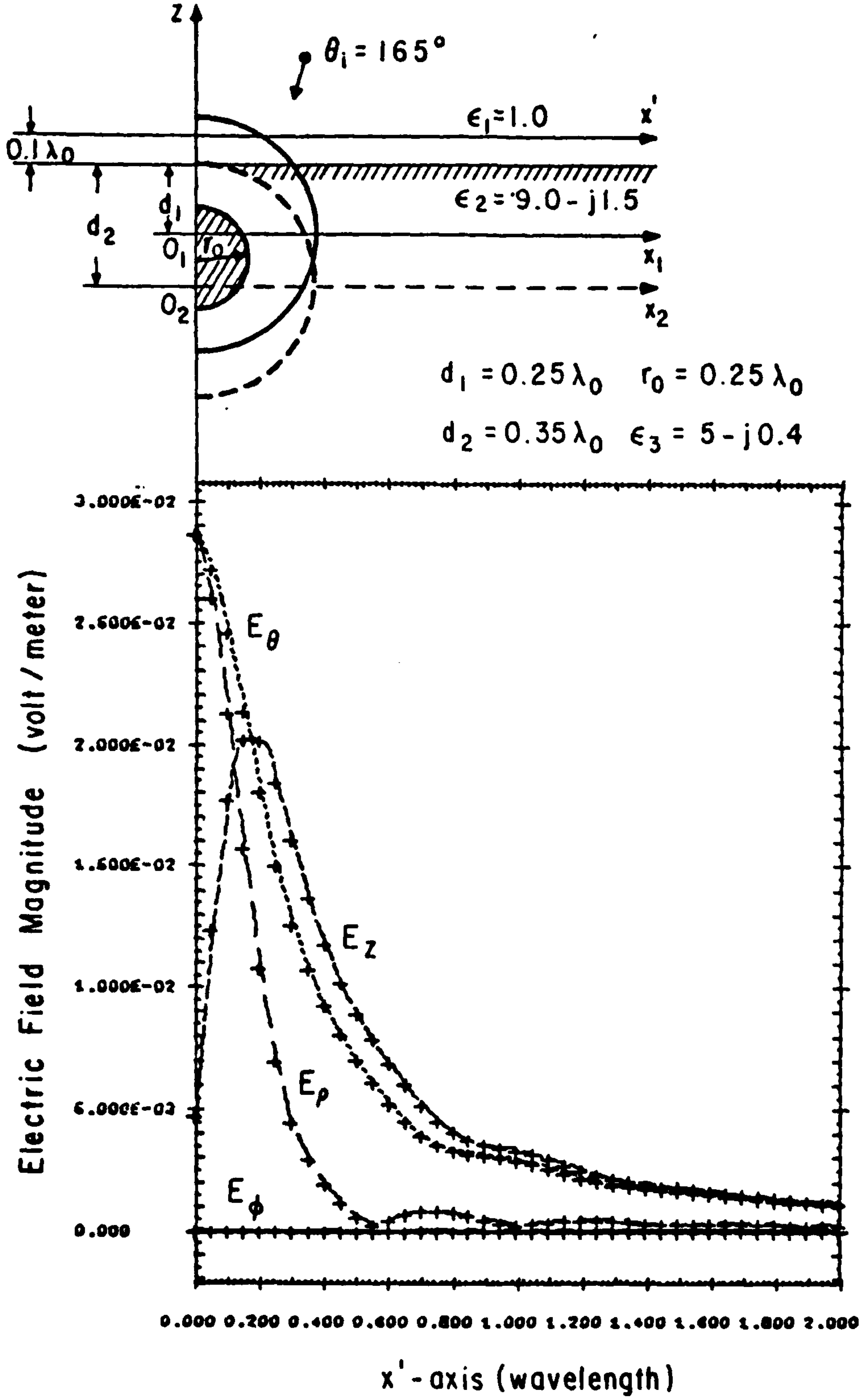

Figure 5. Near Field Above the Interface

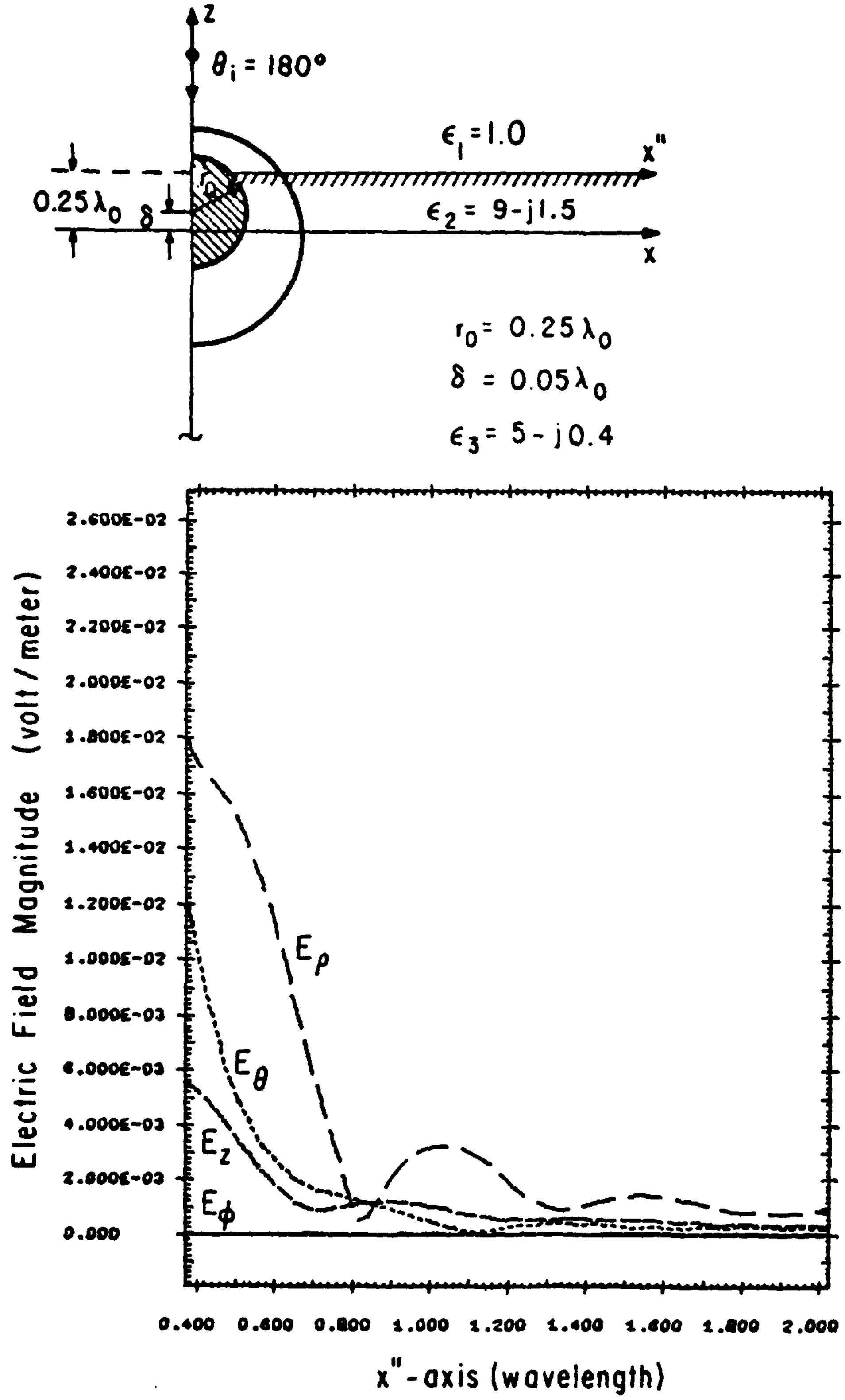

Figure 6. Near Field on the Interface

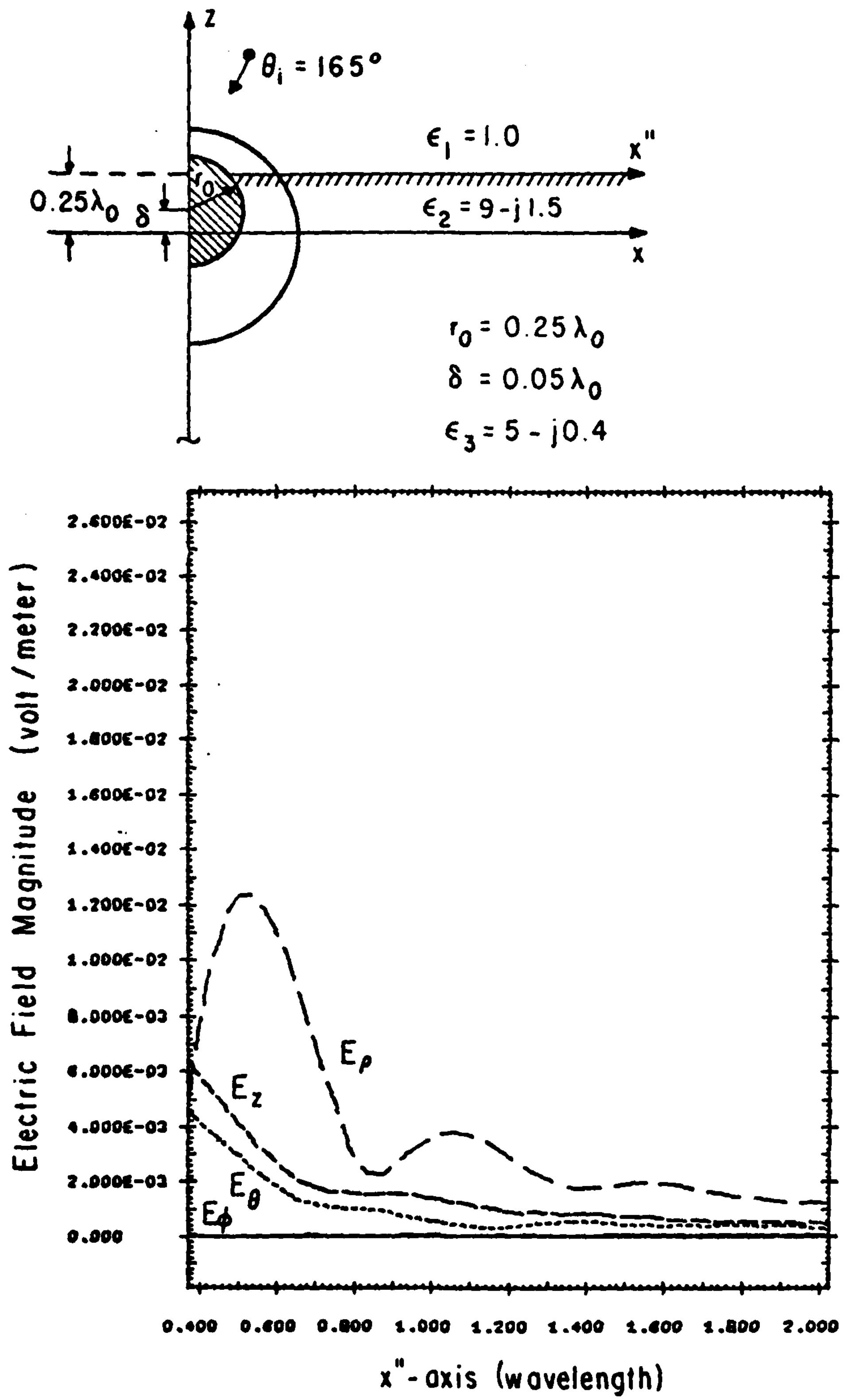

Figure 7. Near Field on the Interface

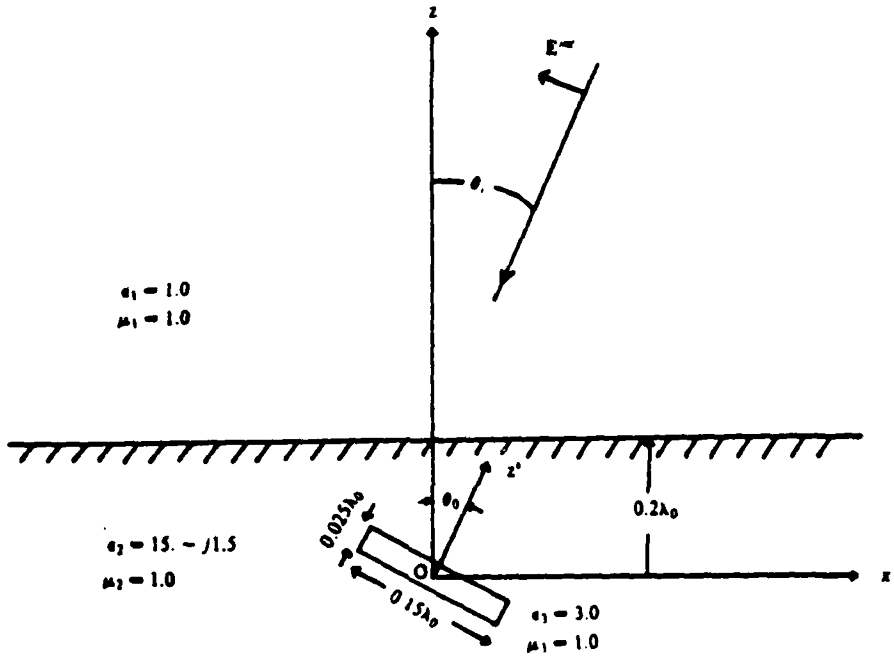

Figure 8. Geometry of the Scatterings from Buried Cylinder with Arbitrary Orientation.

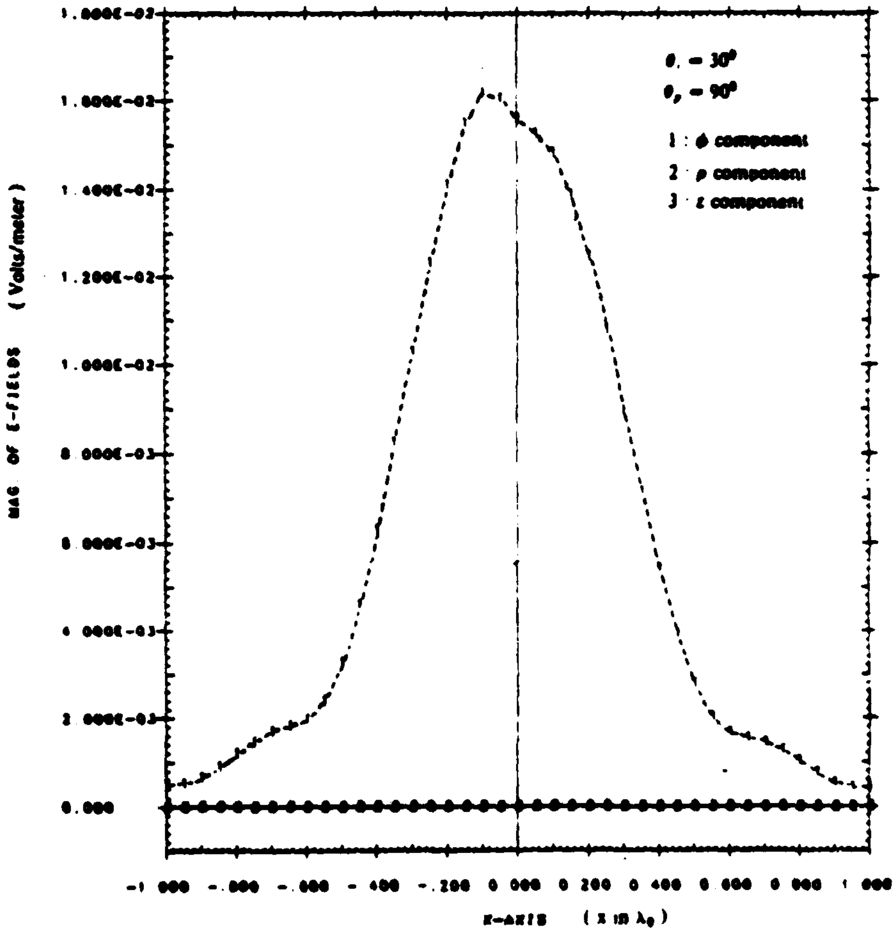

Figure 9. Near Field on the Interface. The Orientation of the Finite Cylinder is $\theta_0 = 0^0$, $\phi_0 = 0^0$.

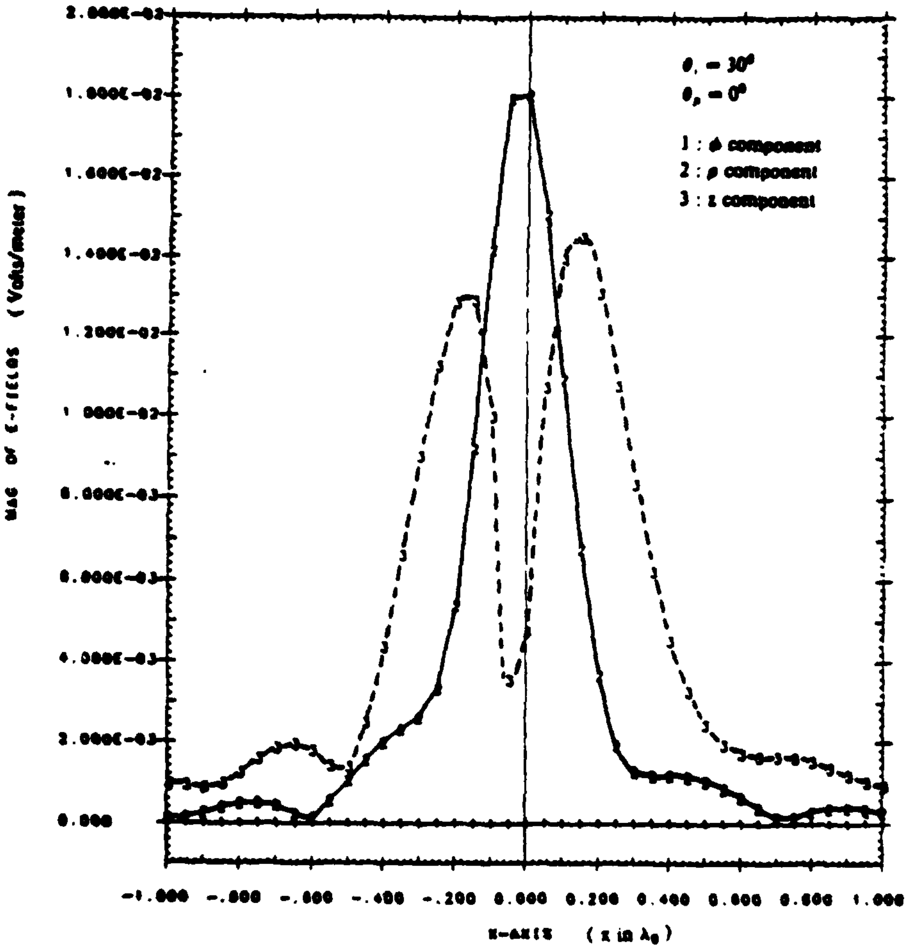

Figure 10. Near field on the Interface. The Orientation of the Finite Cylinder is $\theta_0 = 15°$, $\phi_0 = 0°$

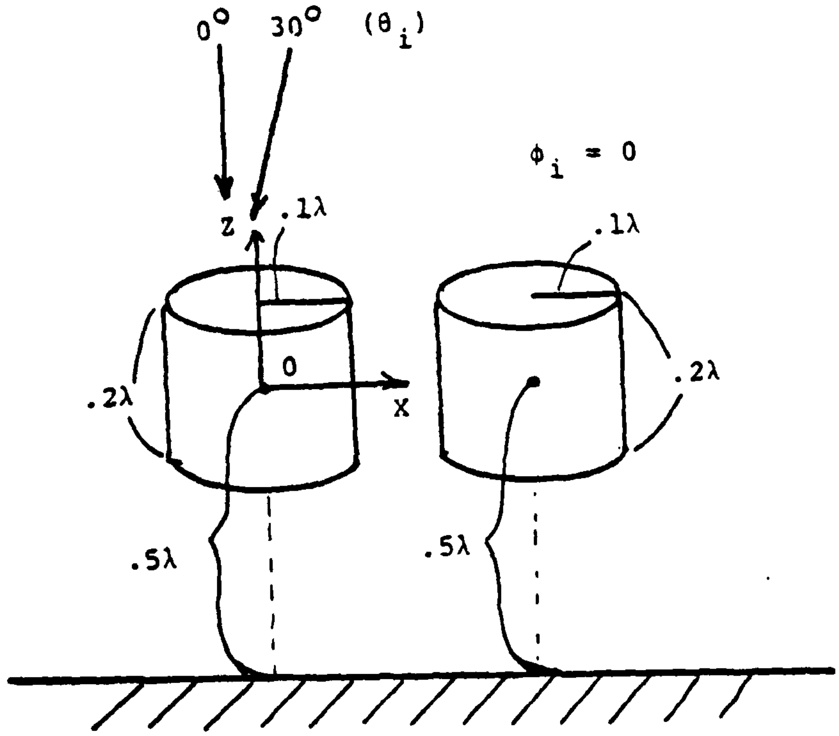

Figure 11. Configuration of Scattering by Two Conducting Finite Cylinders Near Lossy Ground.

Two Conducting Syclinders

Plane wave incident $\theta_i = 0^\circ$

$\phi_i = 0^\circ$

X-Z observation plane

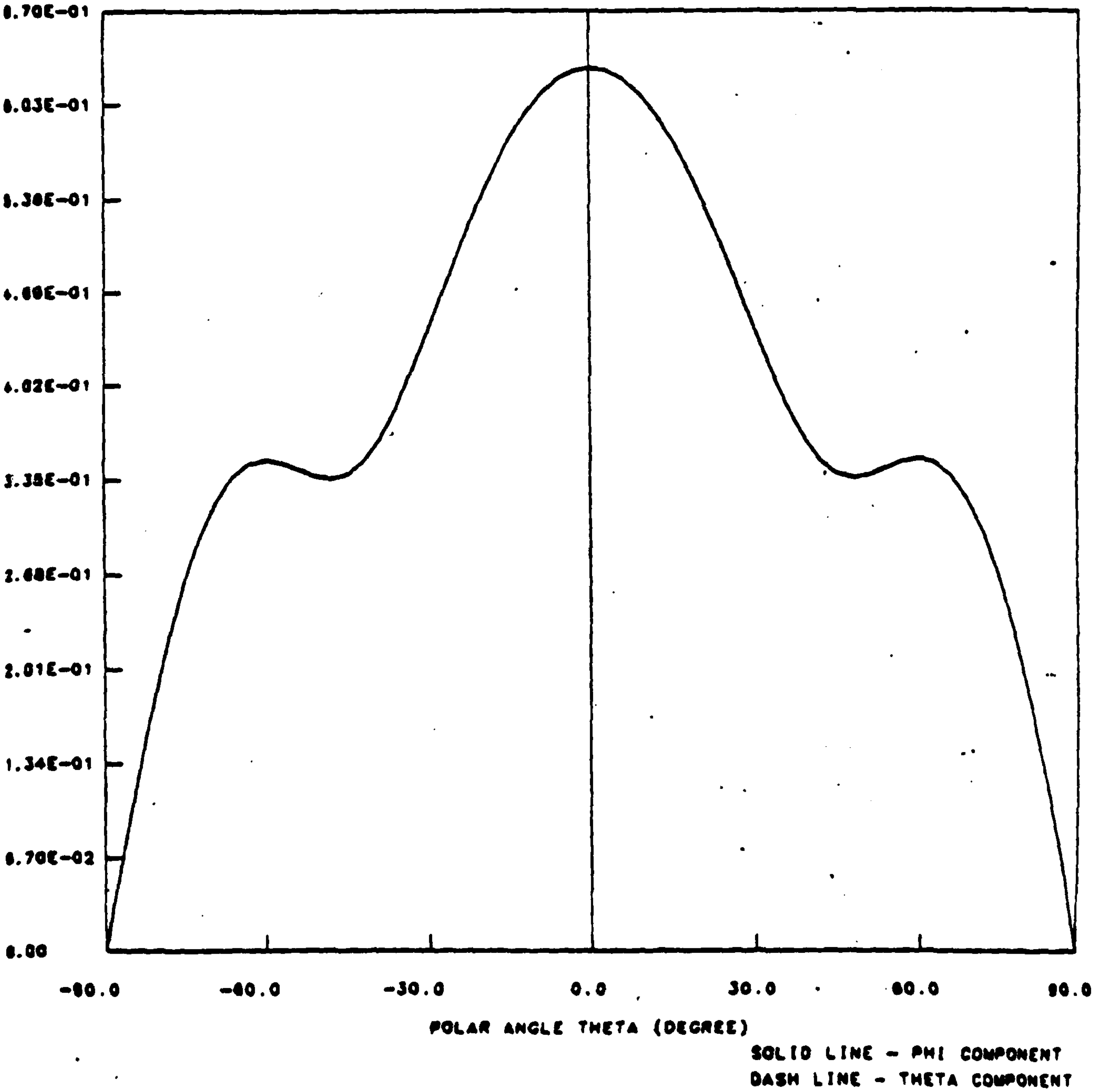

Figure 12. Far Field Pattern of Scattering by Two Conducting Finite Cylinders.

Two Conducting Cylinders

Plane wave incident $\theta_i = 30^\circ$

$\phi_i = 0^\circ$

X-Z observation plane

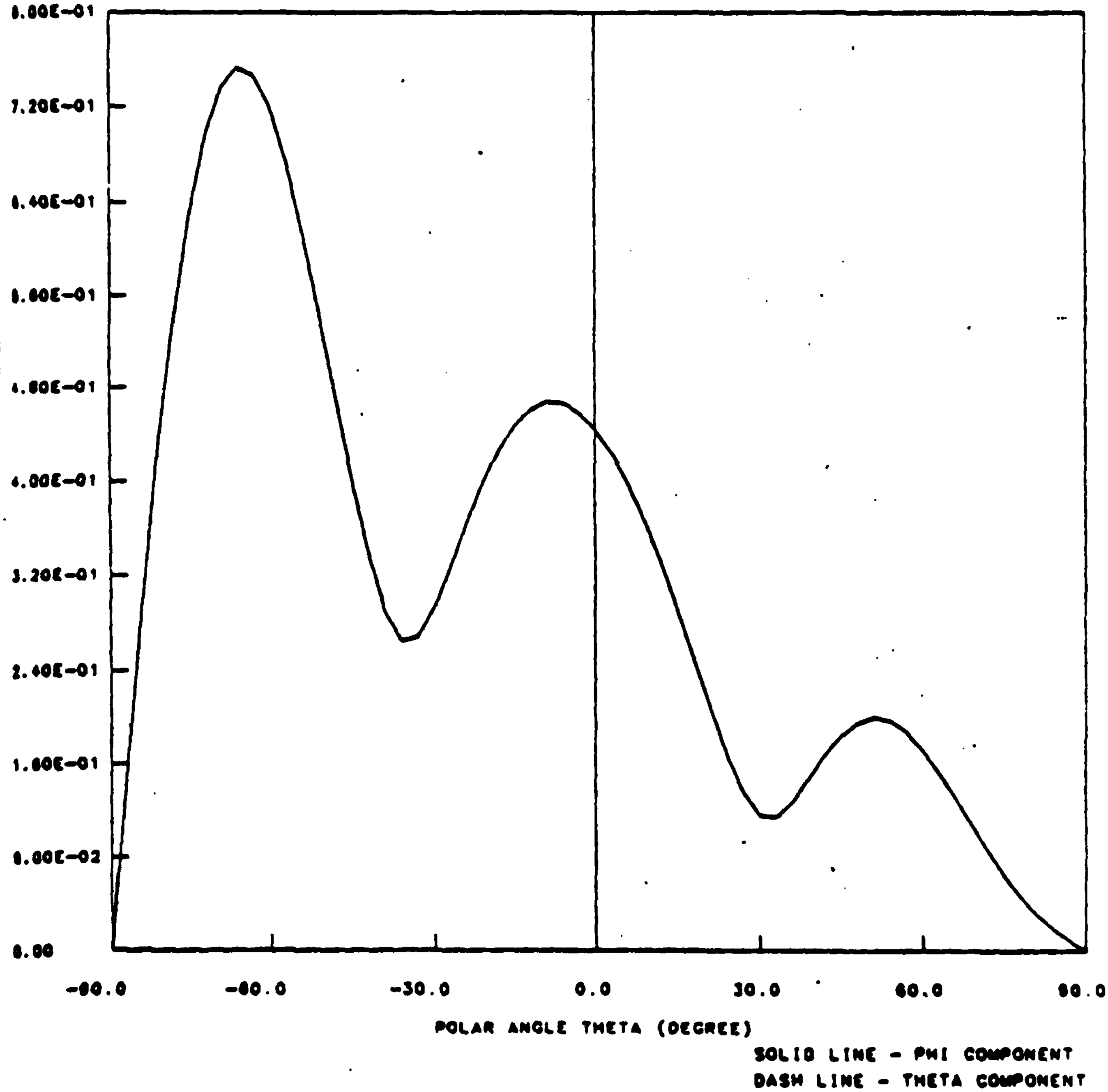

Figure 13. Far Field Pattern of Scattering by Two Conducting Cylinders.

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